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Rainfall variability and rice production in Nigeria: A co-integration model approach

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Abstract

One major key elements of climate change is rainfall which contributes strongly to agricultural productivity. In Nigeria, the production of most food crops is through rain-fed especially rice production. Rice is of national interest and food security concern as it forms a part of an average Nigerian diet and the country depends heavily on importation to meet the citizens' rice demand. Also, low yield has been recorded in local rice production and this has been attributed to various climatic factors but notable, irregularity in rainfall and short period of rainfall. Against this backdrop, it became expedient to study the relationship between rainfall quantity and rice production in Nigeria between 1980 and 2012(32years). Secondary data was used for this study. The analytical tools used are descriptive analysis, trend analysis, Auto-Regressive Distributive Lag (ARDL) model and Error correction model (ECM). The result revealed that between the years 1980 and 2012, total rice yield was 90,630,400 metric tonnes averaging at 2,832,200 metric tonnes per annum while total amount of rainfall for the period was 37,047mm with a mean rainfall amount of 1157.74mm per year. The study found a long run association between rainfall and rice with a long run multiplier effect of 3.151. Rainfall was found to be positive and significant (1.717) in the short run at 10% significant level. The coefficient of the ECM was -1.390 with a high significant probability value of 0.004.The study concluded that dependency on rainfall as the only source of water intake for rice production cannot match the expected rice yield to cater for the populace of Nigeria. The policy implication of the study is that the government of Nigeria needs to invest more in irrigation as another source of water for rice production. This will ensure all year round production of rice which will lead to higher income to rice farmers, reduced importation of foreign rice, reduced poverty and ensure food security of the populace.

Keywords: rice production, co-integration analysis, rainfall, Nigeria

1. Introduction

Climate plays a dominant role and has a direct impact on the productivity of physical production such as soil moisture, fertility and it solely determines the global distribution of crops and livestock as well as their productivity. Both irrigated and rain-fed conditions hinge on the climatic factors like rainfall, precipitation, solar radiation, wind, temperature, relative humidity and other climatic parameters. The short-term departure of these variables from normal either positively or negatively refers to as climate variability (Tiamiyu *et al.*, 2015) and in assessing variability in climate, observation on rainfall and temperature are key parameters (Audu and Rizama, 2012) [7]. In tropical agriculture, rainfall has been found to be the dominating controlling variable since it supplies soil moisture for crops and grasses for animals. Some of the attributes of rainfall that are important to crop production are the time of onset of the raining season, the total amount of rainfall, distribution, the number of rainy days and duration of rainfall as well as the time of its cessation (Akintola, 1994) [2]. Furthermore, rainfall determines the amount of moisture present in the soil which is ultimately made available to plants. Farming output can be adversely affected at any stage from cultivation to final harvest even if there is sufficient rain, its irregularity can affect yields adversely if rains fail to arrive during the crucial growing stage of the crops.

Globally, rice (*Oryza sativa* L.) is a very important food crop especially in Africa, it is a highly strategic and priority commodity for food security. Rice is the single most important source of dietary energy in West Africa and the third most important in the whole continent. Its consumption has been on increase than that of other major staples due to high population growth, rapid urbanization and changes in eating habits (Seck *et al.*, 2013) [32]. Nigeria is one of the largest producers and leading consumer of rice in Africa and simultaneously one of the largest rice importers in the world. Rice is both a food and a cash crop for farmers, contributing to smallholders revenues in the main producing areas (FAO, 2012) [15]. Average annual paddy production is about 4.4million tonnes and the milled product is about 2.8 million tonnes whereas national consumption is estimated at 6 million tonnes of milled rice leaving a shortfall of more than 3 million tonnes that is bridged by importation (Global Agricultural information network, GAIN, 2014). Rice forms the main meal of majority of the people of Nigeria, both rich and the poor, hence providing rice at an affordable price is an important step towards achieving the food self-sufficiency objective of the nation (Seck *et al.*, 2013; Kadiri *et al.*, 2014) [32, 20].

In sub-Saharan Africa, 90 percent of the population relies on agriculture for means of livelihood (Bationo *et al.*, 2003) [16] while 93 percent of cultivated land is rain-fed (FAO, 2002) [14] thus exposes agricultural production to high seasonal rainfall variability. Hence, any changes in rainfall pattern and amount pose a major risk to agricultural production. Intergovernmental Panel on Climate Change, IPCC (2007) [19], exerted that some African nations may experience rain fed agricultural output fall by as high as 50% by 2020 if production methods remain unchanged.

In Nigeria, the production of most crops has been ascertained to be through rain fed and rainfall has also been identified as a key element of climate change and water resources potential which contributes strongly to the success of agriculture in terms of its inter- and intra-annual variability (Adejumo, 2004) [1]. Thus a concern for the effect of rainfall on agricultural productivity especially rice. Two major types of rice are grown in Nigeria; these are upland and swamp rice. The upland rice are majorly grown in waterlogged soil with plenty of water in them while the upland rice grows well under conditions good for the growth of many arable crops. However, the two types require adequate rainfall and shortage of it will lead to crop failure. Rice requires rainfall in sufficient quantity, this is because sufficient moisture for rice promote high quality and high yield, whereas its shortage leads to low quality and yield (Dangana and Muhammed, 2012) [10]. It is also noted that production of rice as of recent been on the decrease due to various climatic factors but notable irregularity in rainfall, short period of rainfall, increase temperature and lower amount of precipitation. (Tiamiyu *et al.*, 2015). At various times, the government of Nigeria has come up with different policies and strategies to encourage improve production of local rice but inconsistent of the policies have led to major drawback ranging from oscillating import tariffs to import restrictions. However, Global Agricultural Information Network, (GAIN) 2014, stated that implementation has been spotty and all supporting infrastructure is grossly inadequate thus making the existing rice production potential not yet realized, as smallholder (small-scale, subsistence and fadama farmers) output is inadequate.

Based on the strong link between rainfall and rice production in Nigeria, it is pertinent to investigate the effect of rain fed agriculture on rice production as this serve as the major source of water for the crop. Various studies have been done on climate and agricultural productivity in Nigeria this includes but not limited to (Tiamiyu *et al*., 2015, Suleiman, 2014, Dangana & Muhammed, 2013, Ayinde *et al*., 2011 and Olanrewaju 2010) [10, 8] but none have been able to look at the effect of rainfall variability solely on rice productivity using the Autoregressive Distributive Lag (ARDL) co-integration approach. The ARDL model analysis will correct for the issue of spurious regression in time series data. The study will also assist policy makers to understand impeding factors affecting rice production in Nigeria as the government of the nation is working towards making the country rice sufficient. With the current government total ban on imported rice, this study is important so that stakeholder strategically work to increase our local rice production to meet the demand of the populace to ensure food security.

Hence, the study will analyze the rainfall and rice output trend between years 1980 and 2012, determine the relationship between rice yield and rainfall in Nigeria between years 1980 and 2012 and look at the effect of rainfall variability on rice output in Nigeria between years 1980 and 2012

2. Methodology

2.1 Data Source

The study made use of secondary data. Nigerian national-level data on rainfall was obtained from publications of World Bank climate change department while national-level data on rice output, area and yield were obtained from International Rice Research Institute (IRRI), United State Development Agency (USDA) version. The data covered the periods 1980-2012. Mean yearly rainfall and rice output yield were computed from the two sources.

2.2 Method of Data Analysis and Model Specification

Objective one was analyzed using trend analysis which shows the variability in rainfall and rice output for the 32 years. The relationship between rice yield and rainfall was tested for using Unit root test. Unit root test was used to test for stationarity while Auto Regressive Distributive Lag (ARDL) model was used to determine (Co-integration) long-run equilibrium between the rice yield and rainfall. Error correction model was used to estimate the short-run effect of rainfall on rice yield for the years.

2.3 Unit Root Test

Conducting regression on a non-stationary time series data over another non-stationary time series data has been proven to produce spurious regression, therefore, there is a need to check for stationarity of the variables (Ehirim *et al*., 2007, Olayemi, 1998 and Phillips, 1986) [13, 26, 33]. According to Giles (2007) [17] the "levels" of many economic time-series are integrated and if these data are used in a regression model then a high value for the coefficient of determination (R_2) is likely to arise, even when the series are actually independent of each other. Stationarity occurs if a series has the means and variances remaining constant over time. It is referred as I(0), denoting integrated of the order of zero, while a nonstationary stochastic series have a varying mean or time-varying variance. A variable that is non-stationary is said to be integrated of order d, written I(d) if it must be differenced d times to be made stationary. In the same way, a variable that has to be differenced once to become stationary is said to be I(1) i.e., integrated of order 1. (Akintunde *et al.*, 2010)

A unit root test was used to test for stationarity and it is performed on both level and first difference to determine whether the individual input series are stationary and exhibit similar statistical properties. According to Gujarati and porter (2009) [18], a unit root test is performed using this equation:

$$Y_t = PY_{t-1} + u_t, -1 \le P \le 1 \tag{1}$$

Where

U_t = the white noise error.

P =estimated P value

When Y_t is regressed on its lagged values of Y_{t-1}, the estimated P value determines its stationarity. When P value is statistically equal to 1 then Y_t has no unit root (non-stationary) but if otherwise then it has a unit root (stationary). This study followed the work done by Ayinde *et al.*, (2011) [8] Augmented Dickey-Fuller (ADF) formula was used to test for stationarity.

$$\Delta Y_t = \beta_t + \beta_{2t} + \delta Y_{t-1} + \sum_{t=1}^{n} \Delta\alpha Y_{t-1} + \varepsilon_t \quad (2)$$

Where

$$\varepsilon_t = \Delta Y_{t-1} = (Y_{t-1} - Y_{t-2}) \quad (3)$$

$$\Delta Y_{t-1} = (Y_{t-2} - Y_{t-3}) \quad (4)$$

Autoregressive Distributed Lag (ARDL) Model

ARDL model was introduced by Pesaran *et al*., (2001) [28] in order to incorporate I(0) and I(1) variables in the same estimation. It uses the bound testing procedure to determine the long-run relationship (cointegration between economic variables. It has some methodological advantages over other single co-integration methods which are:

1. It's appropriateness when economic variables in the model are not integrated of the same order. It can accommodate underlying regressors which are purely I(0), purely non-stationary I(1), or mutually co-integrated, unlike the Johansen approach which deals with the same order of integration.
2. It is suitable for finite and small sample data, unlike other conventional cointegration procedures which require large sample data. This approach was better as the sample data was limited i.e. (32 years).
3. It allows the co-integration relationship to be estimated by OLS once the lag order of the model is identified, unlike other multivariate co-integration methods.
4. The long and short-run parameters of the model can be estimated simultaneously.
5. Testing of hypothesis on the estimated coefficients, in the long run, is possible with this approach, unlike the Engle and Granger method.
6. Bound testing small sample properties have been found to be more superior to that of multivariate cointegration and endogenous problems are also solved. (Naryan, 2005) [22]

The optimal lag length for the specified ARDL model was determined based on the Akaike Information Criterion (AIC) and Schwartz information criterion (SIC). The lag length with lowest AIC & SIC was used in the model and lag 4 was found to be the least. The null hypothesis of no cointegration (long-run relationship) between rice output and rainfall is stated as follows;

Null Hypothesis = $H_0 : \varphi_1 = \varphi_2$

Alternative Hypothesis = $H_a = \varphi_1 \neq \varphi_2$

An F- test (Wald test) of the joint significance of the coefficients of the lagged variables was used to test the hypothesis as it has a non-standard distribution irrespective of whether the variables are 1(0) or 1(1). The F test value is compared to the critical values on the lower and upper bounds on the Pesaran table (Pesaran *et al.*, 2001) [28]. The Pesaran table consists of two sets of adjusted critical values, one set assumes that all variables are 1(0) and the other assumes that they are all 1(1). If the computed F-statistics falls above the upper bound critical value, then the null hypothesis of no cointegration is rejected. If it falls below the lower bound, then the null cannot be rejected. Finally, if it falls between the lower and upper bound, then the result would be inconclusive. Once a long-run relationship has been established, the short-run dynamic relationship is estimated using an unrestricted Error Correction Model (ECM) and the speed at which the dependent variable adjusts to an independent variable within the bounds testing approach can also be estimated. The ARDL model is implicitly stated as:

Annual rice output= f(mean annual rainfall)

Following Pesaran *et al.*, 2001 [28] and the study conducted by Oyakhilomen and Zibah, (2014) [27], cointegration among variables was tested using Unrestricted Error Correction Model (UECM) on ARDL model in eqn (5)

$$\Delta \ln rice_t = \varphi_0 + \sum_{i=1}^{p} \varphi_1 \Delta \ln rice_{t-1} + \sum_{i=0}^{p} \varphi_2 \Delta rain_{t-1} + \beta_1 \ln rice_{t-1} + \beta_2 rain_{t-1} + u_t \quad (5)$$

The long-run relationship can be estimated once the presence of co-integration is noted. This is estimated using the conditional ARDL model specified below:

$$\ln rice_t = \varphi_0 + \beta_1 \ln rice_{t-1} + \beta_2 rain_{t-1} + u_t \quad (6)$$

Error correction model (ECM) is used to estimate the short-run dynamic relationship which is specified as:

$$\Delta \ln rice_t = \varphi_0 + \sum_{i=1}^{p} \varphi_1 \Delta rice_{t-1} + \sum_{i=0}^{p} \varphi_2 \Delta \ln rain_{t-1} + \delta ecm_{t-1} + u_t \quad (7)$$

Where;
Rice= annual rice output in tonnes
Rain= mean annual rainfall in mm
φ_o = constant term
u_t= white noise
$\beta_1 - \beta_2$ = Long-run elasticities (coefficients of the explanatory variable)
$\varphi_1 - \varphi_2$ = Short run elasticities (coefficient of the first-differenced explanatory variable)
ecm_{t-1} = Error correction term lagged for one period.
δ = Speed of adjustment
Δ = First difference operator
Ln = Natural logarithm
P= lag length

3. Results and Discussion

Table 1 revealed that between 1980 and 2012, total rice yield produced in Nigeria was 90,630,400 metric tonnes averaging at 2,832,200 metric tonnes per annum. The quantity of rice yield was at a maximum during the period 2005- 2009 totaling 18,519,710 metric tonnes while it was at a minimum during 1980-1984 with a figure of 4,413,000 metric tonnes. The quantity of rice yield produced in 1980-84 increased from 4,413,000 to 9,132,750 metric tonnes in

1985-1989 which is about 106.9% increment over the previous years in consideration. There was another increase of 58.2% from the year 1990-1994 over the previous year 1985-1989. A decline was experienced in the year 2000-2004 where the yield was found to be 15,428,760 metric tonnes with a percentage decrease of about -2.9% against the year 1995-1999. Subsequently, there was an increase of about 20% in the year 2005-2009 against the year 2004-2009. Increase is also expected to occur in the next five years which follows but the study was limited as it extends only to 2012 which is 3 years in consideration and for 3 years a total of 12,803,220 was recorded. This is expected to increase if considered in terms of the average production. The growth rate of rice output varied between a minimum of -2.9% in the years 2000-2004 and a maximum of 106.9% in 1985-1989 which is at the beginning of Structural adjustment program period (SAP). The growth rate in rice production during 1980-2012 depicts heterogeneity and averaging at 32%. As reported by CBN, (2011) implementation of the various intervention and prevalence weather condition is important for the increase in rice production in Nigeria.

In Table 1, it also shows that total amount of rainfall witness in Nigeria between the year 1980 – 2012 was 37,047mm with a mean rainfall amount of 1157.74mm. The highest amount of rainfall was experienced in the year 1995-1999 with a total of 5934.96mm and least was 5272.62mm in the year 1980-1984. Rainfall amount increases with about 1.5% in 1985-1989 as against 1980-1984. Also, there was an increase of 5.5% and 5.1% in 1990 -1994 and 1995-1999 respectively. A decline experienced in 2000-2004 with a decrease of about 4.3% as against the previous year 1995-1999. The same year, (2000-2004), rice also experiences a downward trend in yield output. The last year on the table was not fully considered as it does not contain up to the numbers of other classes. Figure 1, 2 and 3 shows that quantity of rice yield and rainfall amount increased and decreased severally under the year's study.

Table 1: Trend in rice yield output and rainfall in Nigeria (1980-2012)

YEAR	RICE(1000mt)	Rainfall (mm)	Change In Rice (1000mt)	Change In Rainfall(mm)	% Change In Rice	% Change In Rainfall
1980-1984	4,413,000	5272.62	-	-		
1985-1989	9,132,750	5353.81	4,719,750	81.18	106.9	1.5
1990-1994	14,449,680	5649.44	5,316,930	295.63	58.2	5.5
1995-1999	15,883,189	5934.96	1,433,500	285.52	9.9	5.1
2000-2004	15,428,760	5659.49	-454,429	-257.46	-2.9	-4.3
2005-2009	18,519,710	5852.80	3,090,950	193.30	20.0	3.4
2010-2012	12.803.320	3324.62	-5,716,390	-2528.17	-0.02	-43.19
Total	90,630,400	37047.74	8,390,320	-1947,99		
Mean	2,832,200	1,157.74			32.0	-5.33

Source: International Rice Research Institute (IRRI) USDA version (1980-2012) and World Bank Climate Change Report (1980-2012).
Note: Changes and % changes in rice yield and rainfall were author's computation.

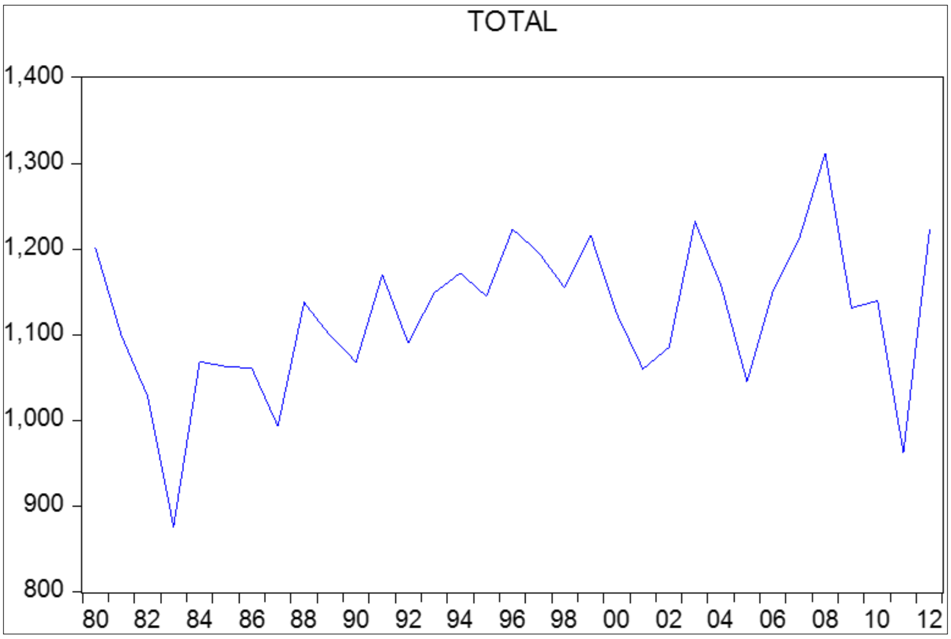

Fig 1: Trends in rainfall (mm) in Nigeria (1980-2012)

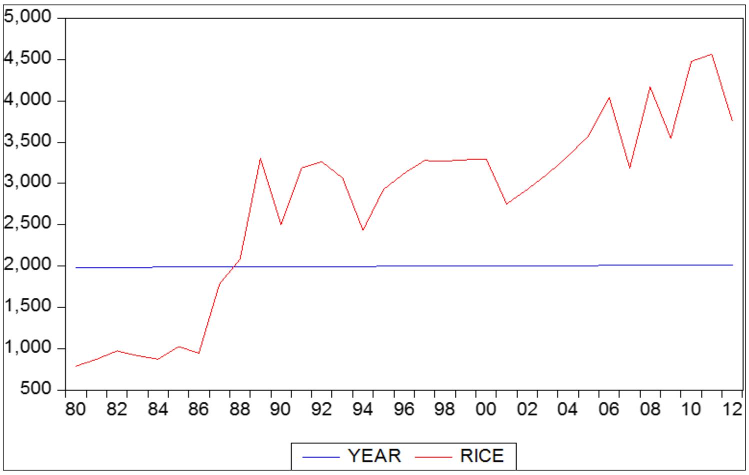

Fig 2: Trends in rice yield production (1000mt) in Nigeria (1980-2012)

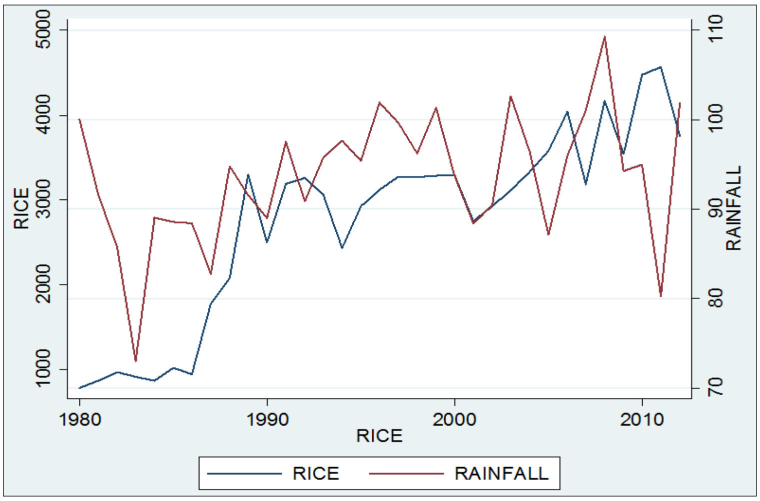

Fig 3: Trends in rainfall (mm) and rice output (MT) in years 1980-2012

The data on rice yield and rainfall in Nigeria between 1980 - 2012 was further analyzed to determine if there any relationship between rice yield output and rainfall. This was done by using the ADF for unit root testing; ARDL was to determine the long run relationship and unrestricted error correction model estimate for short-term dynamic effect between the rice and rainfall.

3.1 Augment Dickey-Fuller (ADF) Testing

Unit root testing was conducted to ensure that none of the variables are integrated of order 2 and above because of the computed F statistics and critical values provided by Pesaran *et al.*, (2001) [28] are valid for variables that are integrated of order 1, 0 or mutually cointegrated. Table 2 below shows the result of the unit root testing.

Table 2: ADF Testing Result

		Level	First difference		
Variable	T Statistic	Probability	t-statistic	Probability	Decision
Lnrice	-1.995	0.2871	-7.218	0.0000	I(1)
Lnrain	-4.149	0.0029			I(0)

Source: Authors Computation, 2017 from E-views 7.1

A decision can be taken based on either the t-statistics or p-values (probability). The probability below 5% shows that the variable has a unit root and above 5% indicates no unit root. The null hypothesis was accepted for rain because it has a unit root at level while it was rejected for rice because it does not have unit root at level so it was further differenced. At first differencing, it was found to be stationary. Lnrain is stationary at level (I(0) while lnrice was found to be stationary at first difference I(1). We, therefore, proceed to use the ARDL as the variables are of different order of integration.

3.2 ARDL Bound Test of Co-Integration

Table 3 reveals that there is a long run association between the rainfall and rice. The null hypothesis is c(10)=c(11)=0 The F-statistic was gotten using the Wald's test and it was found to be 5.00. The F-statistics value is compared with the Pesaran critical value at 5% level. When the F-statistics is more than the upper bound value we can reject the null hypothesis. In this study, the F-statistics was calculated to be 5.00 and the lower bound value is 2.86 and upper bound value is 4.01. Therefore the null hypothesis is rejected. This shows that there is a long run association between rainfall and rice.

Table 3: ARDL Bound Test of Co-Integration

Critical Value	Lower Bound Value	Upper Bound Value
1%	2.45	3.52
5%	2.86	4.01
Computed F-statistic: Flnrice (lnrain)=5.00		

Source: Author's Computation, 2017 from E-views 7.1

Note: Critical Values are cited from Pesaran *et al.* (2001) [28], Table CI (iii), Case 111: Unrestricted intercept and no trend for K = 4.

3.3 Estimate of Long Run Relationship between rice yield and rainfall (1980-2012)

Table 4 shows the result of the estimated coefficients of the long run relationship. Though none of the coefficients was found to be significant, the long run multiplier effect between rice and rainfall is (0.2679/0.0859) = 3.151.This implies that in the long run, a unit increase of rainfall will lead to an increase of 3.151 units in rice output yield.

Table 4: Estimate of long-run association between rice yield and rainfall within (1980-2012)

Variable	Coefficient	T statistics	Prob
C	1.790	0.267	0.792
D(lnrice(-1))	-0.223	-0.903	0.379
D(lnrice(-2))	0.227	1.107	0.283
Dln(rice(-3))	-0.183	-0,895	0.383
D(lnrice(-4))	-0.024	-0.116	0.909
D(lnrain(-1))	0.443	0.285	0.779
D(lnrain(-2))	0.326	0.283	0.780
D(lnrain(-3))	1.202	1.498	0.152
D(lnrain(-4))	0.797	1.347	0.196
Lnrice(-1)	-0.268	-1,431	0.171
Lnrain(-1)	0.086	0.004	0.962
R-squared	0.604	F statistic	2.590
Adjusted R-squared	0.371	Prob(F statistic	0.040
Log likelihood	17.999	Durbin-Watson Stat	2.322
Akaike Info Criterion	-0.499	Schwarz criterion	0.023

Source: Authors Computation, 2017 from E-views 7.1

3.4 Estimated Short Run Relationship

Table 5 shows the coefficients of the estimated short-run dynamics in line with the long-run relationship obtained from the ECM. The coefficient of the ECM was found to have a correct sign which is negative i.e. -1.390 and the probability value of 0.004 is also highly significant. This shows that the speed of adjustment to equilibrium aftershock is very high 139%. This implies that about 139% of disequilibria from the previous year's shock return back to the long run equilibrium in the current year. Rainfall was found to be positive and significant (1.717) in the short run at 10% significant level. The estimated coefficient of rainfall (1.654) reveals that 1% increase in rainfall will increase rice output by 1.65% in the short run.

Table 5: Error Correction Model (short-run dynamics) between rice and rainfall in Nigeria (1980-2012)

Regress or	Coefficient	Standard Error	T. Ratio	Prob
Lnrain	1.654	0.963	1.717	0.107
Ecm(-1)	-1.390	0.774	-1.796	0.04
R squared	0.6778	Prob F statistics	0.030	
Adjusted R squared	0.4414	Log-likelihood	19.799	
F-statistics	2.868	Durbin Watson	1.737	

Source: Author's Computation. From E-views 7.1

The R-square value shows that our dependent variable has 67.7% influences on the model while the 44 is the residual value. The probability (F-statistics) is below 5%. This explains the overall significance of the model. The D statistics is also close to 2 and we can conclude that there is no autocorrelation in our model.

Diagnostic Tests

The stability of the coefficients over the sample period (32 years) was tested for using the cumulative sum (CUSUM) and the cumulative sum of square (CUSUMQ). Figure 4 and 5 shows that the plot of CUSUM and CUSMQ fall inside the critical bands of the 5% confidence interval. This explains that the model is stable. Table 6 presents the diagnostic test and it shows the model passed the entire test. This was used to infer that the model residuals are not serially correlated, no heteroscedasticity. The choice of functional form is also correct and the model is also normally distributed

Table 6: Ardl diagnostic test

Test Statistics	Chi2	Probability
Serial LM correlation	0.752	0.261
Heteroscedasticity	13.006	0.831
Functional form	1.306	0.318
Normality	0.536	0.536

Source: Author's Computation. From E-views 7.1

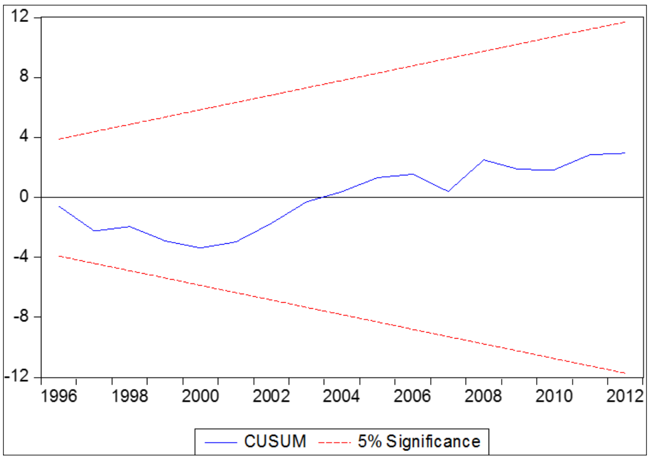

Fig 4: CUSUM Test

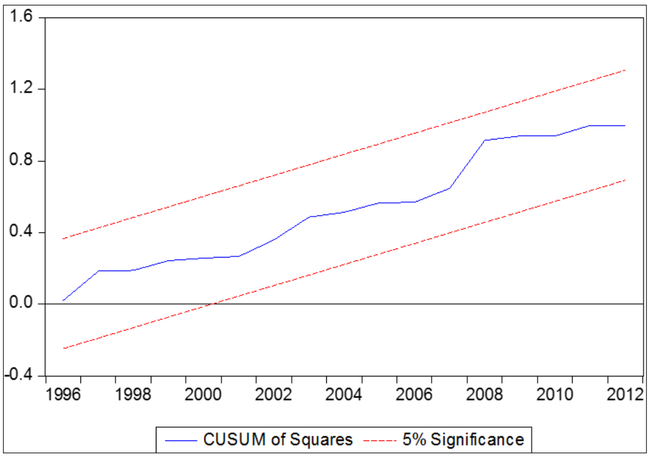

Fig 5: CUSUM of Square Test

4. Conclusion and Recommendations

The study concluded that there is both long and short run association between rice and rainfall. It was revealed that in years where rainfall was low, decrease was also experience in rice yield for the years. This, therefore, shows that rainfall has an impact on rice production in Nigeria. With the incessant and irregularity rainfall in Nigeria, rice production in the country is grossly affected as two or more growing period cannot be achieved. Cessation of rainfall during growth of rice also affects its yield. Though other climatic factors such as temperature, dry spells can also contribute to the reduced rice yield.

Dependency on rainfall as the only source of water intake for rice production cannot match the expected rice yield to cater for the populace of Nigeria owing to the high level if intake of rice in the country. Therefore the availability and affordability call for a national concern in term of food security. The government of Nigeria should invest more in irrigation as another source of water in rice production such that water needs will not be rainfed only. This will also ensure all year round production of rice which will lead to higher income to rice farmers, reduced importation of foreign rice, reduced poverty and improved food security of the populace. The point of cessation or irregularities in rainfall during the growing period of rice can also be supplemented with irrigation which will also prevent low yield and outright loss of food crop to rice farmers.

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